FERMILAB-LU-199

Fermilab

April 21, 1993

Linac Upgrade Note, **LU-199**

# Transverse Emittance & Twiss Parameters Calculations

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A new application program to calculate the transverse emittances using three wire measurements is being developed. The following is a quick description of the present status of the program and the work still in progress.

Actual wire measurements are taken from another application program. Results of the measurements are stored in the FileShare area and subsequently read by the transverse emittance program. The beam size at each wire, necessary to calculate the final emittance, is derived from a Gaussian fit to the data. The core of the program starts by calculating the first order and second order moments of the beam profile at each wire and in each plane x,y, and u (if available). These values are then used as initial guesses to do a Gaussian fit to the profile shape. This ensures the convergence of the method in finding the best fit and eliminates the need for the user to enter an initial guess. The fit is based on a nonlinear modeling procedure called the Levenberg-Marquardt method that works very well in practice and has become the standard of nonlinear least-squares routines. This iterative method is repeated until a minimum $\chi^2$ is found. The method is quite flexible and allows for different type of functional fits together with an assumed measurement error at each data point. So far only Gaussian fit has been implemented but the program can accommodate other fitting functions like a parabola or a cosine.

The program also incorporates the proper logics to disregard suspicious points. A point is rejected from the fit if the corresponding step jump in the wire position is greater than a previously specified value (defined as 0.3 in the program). Such big jumps have been observed in some wire scans. As more possible source of errors are defined, the proper logic will be added to the program to eliminate such points from the fit.

Another source of error is the background noise. By entering an estimate of the noise level the code can subtract this effect from each datum before entering the fitting routine.

The beam width at each wire changes with the percent of the beam we want to represent and the final emittance becomes a percent beam emittance. The code allows for various percent emittances to be calculated based on three different approaches. In the first approach the percent emittance represents the percent of the maximum voltage reading for a given wire scan before the Gaussian fit. Any reading less than that percent is excluded from the Gaussian fit. The width of the Gaussian fit to the remaining data is then the width of the beam used in deriving the emittance. Contrary to the previous method the second approach applies the percent emittance to the maximum voltage of the fitted Gaussian profile. Finally, in the third approach the percent emittance represents a percent area under the Gaussian fit. The beam size is equal to the width from the selected percent area. For example, it is very common for proton machines to select a beam size equal to 95% of the beam. All three methods are available to the user. The program also calculates the twiss parameters in all planes at the location of the first wire.

## Description of the Input/Output

The input data from the user include the desired percent emittance (any number from 0 to 100 can be entered). To start with and for immediate testing of the program the proper transfer matrices for a three wire measurement in the 200 MeV line are included in the code. The transfer functions can be calculated using a variety of available codes. For these calculations the code TRACE3D was chosen. Any emittance calculation program should allow for real time readings of the quadrupoles gradient. This information is fed into a code like TRACE3D to calculate the correct transfer functions corresponding of that day wire measurements. This work is in progress. Other input functionalities will include an entry for the background noise level, and a selection from the three approaches discussed earlier to calculate the percent beam emittance. The plan also calls for the selection of any three wire combination available from a list of wires. This latter requires an interface to a TRACE3D like code to derive the corresponding transfer matrices for different combinations.

The output functionalities of the program so far include a display of the emittance value and twiss parameters in both the horizontal and vertical plane. A display in the skew u-plane will also be added. Work is in progress to generate plots of the beam profile and the fitted profile at each wire and in each plane together with information on the obtained $\chi^2$ error and the three parameters, amplitude, average, and variance, defining the Gaussian fit. Plot of the emittance versus the percent number of the beam will also be an integral part of the output.

The application program is written to run on the ACNET control system. The program is written in C and is now running in its simple form on a linac page.